FINAL REPORT

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SPECTRAL REFLECTANCE OF PLANETARY SURFACES

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This report emphasizes the final year of the grant period. Earlier work, dating back to 1981 is summarized in the publications that are cited below.

Detectability Analysis. An overall theme of our research has been to evaluate and interpret spectroscopic evidence for compositional variability on Mars. We have assessed the compositional variability that could be detected spectroscopically under computer-simulated "best case" conditions using all available wavelength measurements. We used laboratory spectra of Martian analog materials including basalt, weathered basaltic palagonite and other mineral and rock types. Laboratory spectra were convolved with Viking Lander and Viking Orbiter spectral channels and the resulting pseudospectra were analyzed for detectability. In the detectability analysis the spectrum of one material is evaluated relative to a specified background which may consist of one or more spectrally distinct materials. The detectability of the "target" material depends on the spectral contrast with the background and on system parameters, including the number and wavelength of the camera channels and the signal-to-noise ratio of the measurements.

Simulations also were made of telescopic spectra by normalizing laboratory spectra at 0.56um. Detectability thresholds were then determined for various target materials and backgrounds. Thresholds were measured at different signal-to-noise levels for laboratory measurements and for the simulated Viking Lander, Viking Orbiter, and telescopic data. Our results indicate that there is a wide range of detectability thresholds for Martian analog materials and that, in general, detectability of most materials is poor for systems with few channels such as Viking Orbiter, and that it also is poor for normalized data such as the telescopic measurements.

An example is the detectability threshold of andesitic ash (Mt. St. Helens) in a background of basalt and weathered basaltic palagonite. We posed the question: how much andesitic ash would have to be present to be spectrally detectable in the presence of basalt and palagonite? Alternatively, if the present spectroscopic and other evidence is correct that the surface of Mars is dominated by basalts and weathered palagonitic dust, what other materials (such as andesite) might be present that might be spectrally indistinguishable from the two main materials and their mixtures? We showed that andesitic ash is detectable using laboratory spectra at amounts of a few percent. However, when measured by Viking Orbiter the ash must be a major component of the surface to be detected. Similarly, to be detected in the telescopic spectra with a signal-to-noise ratio of 50:1 the andesitic ash would have to comprise 15 to 20% of the surface.

The poor detectability of andesitic ash in the telescopic simulation occurs in spite of high spectral resolution. The problem lies in the normalization of the data which eliminates the "albedo" information. Most researchers analyzing telescopic spectra today work with normalized data because they are interested primarily in identifying specific absorption bands that can be assigned to minerals. Unfortunately, most absorption bands in the Martian spectra are weak (excepting the $Fe3+$ ones) and it is difficult to isolate weak mineral bands from atmospheric ones and from the instrumental noise. Current debates about scapolite illustrate the point.

Telescopic measurements are not being used to full advantage. Our modeling results indicate that if the albedo information could be recovered from the telescopic data the detectability of all materials would be increased substantially. For example, one then could examine whether a large fraction of scapolite would be detectable using the measurements over the rest of the spectrum, outside of the absorption bands. We are aware of the reasons for making normalized telescopic measurements, and of the difficulties in acquiring absolute data. However, the effort may be worthwhile.

Telescopic CCD Images. Beginning in 1988 and continuing through 1990 a large number of high spectral resolution CCD images were acquired at Mauna Kea and Pic du Midi. Some of these data have been published and some are being reduced. Although of very high spectral resolution, these measurements have been difficult to calibrate and, therefore, have been difficult to compare and to interpret in terms of laboratory reference spectra. This fundamental problem of calibrating spectral measurements that are obtained by various instruments under different illumination and atmospheric conditions has been one focus of our research for several years.

Part of our research effort in the past year has been to calibrate and interpret high spectral resolution telescopic spectra and CCD images in collaboration with T. McCord, J. Bell, and P. Pinet. In working with the telescopic CCD data we have addressed one particularly difficult problem, namely, that spectra are affected by the rotation of Mars during and between measurements. When spectral measurements are sequenced in time the field of view shifts as a function of wavelength. Smearing during measurement at a single wavelength increases the instantaneous field of view; however, movement during multiple (wavelength) measurements poses a difficulty in registering the multispectral data into an image cube. Registration can be approximated by shifting pixel arrays by a time-distance function, but accurate registration requires tie- points on the surface. Unfortunately, surface features vary in contrast with wavelength, and cannot be counted on for registration.

Terrestrial analogs. We have been working with J. Bell (U. of Hawaii and our laboratory) and R. Morris (JSC) to further evaluate the spectra of the bright areas of Mars in the visible and near-infrared. We have found a new sample of Hawaiian palagonitic tephra that has the best fit that we have seen so far to the telescopic spectra of martian dust. The sample occurs at the contact between a basalt dike and a basalt tephra cone. We have proposed that the palagonitic sample formed under conditions that also could have occurred on the surface of Mars as a result of volcanic or impact thermal pulses applied to basaltic tephra containing adsorbed water or ice. We have examined the magnetic and Mossbauer properties of the iron phases in the sample, and have evaluated the reflectance spectra in terms of the iron oxide / oxyhydroxide mineralogy.

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